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The integrated Herbst appliance—treatment effects in a group of adolescent males with Class II malocclusions compared with growth changes in an untreated control group

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SUMMARY In this study, the effect of the integrated Herbst appliance (IHA) was examined in 30 Swedish males (mean age 14.2 ± 0.96 years) with a Class II malocclusion. An evaluation of hand–wrist radiographs showed that the patients were in the maturation stages MP3-F, MP3-FG, or MP3-G at the start of treatment. The average treatment time with the Herbst mechanics was 0.7 years. Dentoskeletal and soft tissue parameters were analysed on lateral radiographic head films taken at the start and end of the IHA treatment. The pre- and post-Herbst values of a number of skeletal and dental variables in the treatment group were compared with the corresponding values in a group of untreated age-matched males with Class II malocclusions. Differences in the cephalometric measurements pre- and post-Herbst treatment were determined using paired *t*-tests.

In general, the control group exhibited only minor or no changes during the period of observation, whereas treatment with the IHA resulted in statistically significant and favourable changes of the recorded variables. In the IHA patients, ANB angle was reduced on average by 2.1 degrees. However, a skeletal post-normality (ANB = 3.9 degrees) remained even though a Class I dental relationship had been obtained. In comparison with treatment effects achieved with other designs of Herbst appliances, some minor differences in the changes of the variables SNA and ML/NSL were noted in the present study. These differences could probably be attributed to the particular treatment protocol which was applied in the IHA treatments.

Introduction

The efficacy of the Herbst appliance in normalizing the sagittal dental arch relationship in patients with a Class II division I malocclusion is well documented. The correction is partly achieved by anterior mandibular tooth movement and incisor proclination, as well as by posterior movement of the maxillary teeth. The use of the Herbst appliance also results in increased mandibular condylar growth (Pancherz, 1979, 1982; Paulsen, 1997; Paulsen *et al.*, 1998; Manfredi *et al.*, 2001) and glenoid fossa remodelling (Woodside *et al.*, 1987; Ruf and Pancherz, 1999; Voudouris *et al.*, 2003a,b).

The Herbst appliance was first introduced in 1905 (Herbst, 1934). Schwarz (1934) presented a number of improvements of the dental anchor age system. After a period of virtual oblivion, the Herbst appliance was re-introduced by Pancherz (1979). Since then, several modifications of the original design have appeared. Examples of this are the bonded Herbst appliance with upper and lower acrylic splints (Howe, 1982), the cast splint Herbst appliance in combination with headgear (Wieslander, 1984), the Herbst appliance with a mandibular acrylic splint and stainless steel crowns on the maxillary first molars (Valant and Sinclair, 1989), and cast splints equipped with a Herbst mechanism with ball and socket hinges (Herbst IV®).

The design of the Herbst appliance used in the present study has been previously described in detail (Haegglund and Segerdal, 1997). The development of this appliance was started in 1986 when the authors focused on finding a simple way of integrating the Herbst mechanism with a standard upper and lower fixed appliance. With such an arrangement, the complete fabrication of the Herbst appliance could be performed in the clinic without involvement of a dental technician. Furthermore, possible problems with the appliance during treatment could be immediately and easily solved in the clinic, making involvement of a dental laboratory unnecessary.

The aim of the present investigation was to study the treatment effects of this modified Herbst appliance on a number of dentofacial variables and compare the skeletal, dental, and soft tissue profile changes with the corresponding morphological changes of an untreated group of subjects with a post-normal occlusion.

Materials and methods

The records of 174 patients who had undergone treatment with the integrated Herbst appliance (IHA) at the Clinic of Orthodontics in Sundsvall, Sweden, were analysed as a part of a treatment quality project. The following radiographic records were available for each patient:

1. Standardized lateral cephalometric radiographs at the start and termination of Herbst treatment.
2. Hand-wrist radiographs taken at the time of insertion of the Herbst appliance.

From these patients, a consecutive group of Caucasian boys who fulfilled the criteria listed below was selected for the present investigation.

1. No extractions of the permanent teeth either before or during Herbst treatment.
2. The skeletal maturation phase at the start of Herbst treatment should be MP3-F, MP3-FG, or MP3-G (from onset of the pubertal growth spurt to peak) as evaluated on the hand-wrist radiographs (Hägg and Taranger, 1980, 1982). Two investigators (PH and SS) evaluated the radiographs. Any disparities in the assessment of skeletal maturation were discussed until consensus was reached.
3. ANB angle ≥4 degrees and overjet ≥6 mm after levelling of the teeth with fixed appliance.

Thirty-one boys fulfilled these criteria. However, one boy exhibited a considerable delay in skeletal maturation as a consequence of which his chronological age at the start of treatment was comparatively high. Since the control records did not cover such high age levels, this subject was excluded from the study.

The dental maturity of the patients corresponded to the dental stages DS4/M1 ($n = 2$) or DS4/M2 ($n = 28$).

All patients had at least an end-to-end Class II molar relationship before treatment. In three of the 30 patients, the malocclusions were diagnosed as Class II division 2. During the alignment phase, i.e. before insertion of the IHA, these dentitions were changed to a Class II occlusion with normally inclined or slightly proclined upper incisors.

Ten of the patients had previously undergone activator treatment with poor results due to lack of compliance.

The Herbst treatments had been carried out by three orthodontists using basically the same technique. At the start of treatment, the mean age of the subjects was 14.2 ± 0.96 years (range 12.5–16.2 years). At this stage, three patients were in maturation phase MP3-F, three in MP3-FG, and 24 in MP3-G. The average treatment time with the IHA was 8 months and 13 days (0.70 years, range 0.5–0.9 years). Consequently, the mean post-Herbst age was 14.9 ± 0.95 years (range 13.2–16.8 years).

Before insertion of the IHA, the dental arches were levelled with upper and lower fixed appliances, which included bands with headgear tubes on the upper first molars and bands with a rectangular and a round tube (0.036–0.045 inch) on the lower first molars. The inclination of the upper and lower anterior teeth was also adjusted, and the incisors were intruded when necessary. After this initial treatment procedure, which took on average 9.3 months, heavy rectangular stainless steel arch wires in the upper and lower jaw and the Herbst appliance could be inserted (Haegglund and Segerdal, 1997, Figure 1). Apart from some minor improvements of the connection between the Herbst components and the fixed appliance, no changes to the appliances were carried out during the period of investigation.

The control subjects, who were of Austrian origin, were selected from the cross-sectional roentgen cephalometric material of orthodontically untreated children and adolescents presented by Droschl (1984). The diagnosis of a Class II malocclusion was applied when there was a Class II relationship exceeding one-quarter premolar width, increased overjet, and incisor protrusion. In the age interval, which corresponds to the pre-Herbst age range of the treatment group (12.5–16.2 years), this material comprised 64 males with post-normal occlusion. Seventeen of these subjects had to be excluded due to the fact that they exhibited an ANB angle and/or an overjet smaller than 4 degrees and 6 mm, respectively. After this reduction, the control group for pre-Herbst comparisons comprised 47 subjects. The control group for the post-Herbst comparisons was selected in a similar way, and 33 control subjects were available in the age range 13.2–16.8 years.

According to the Greulich and Pyle (1959) method, the skeletal age of the controls was estimated to be retarded, 4.6 months on average, in relation to chronological age. However, when this assessment was performed on the same material using the method of Tanner and Whitehouse (Wenzel *et al.*, 1984), a closer agreement between skeletal and chronological age was found. These results suggest that the majority of the control subjects could be expected to be in the maturation stages MP3-F, MP3-FG, or MP3-G (Hägg and Taranger, 1980, 1982; Hägg and Pancherz, 1988).

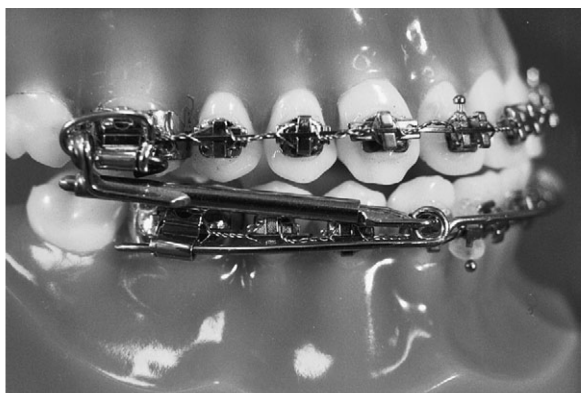

Figure 1 The integrated Herbst appliance. The Herbst pistons are connected to an auxiliary arch wire (0.9–1.0 mm). This arch wire is inserted in round tubes on the lower first molar bands and anteriorly attached to the main arch wire with elastomeric modules. The Herbst tubes are attached to the headgear tubes on the upper first molar bands with hooks made of 0.9–1.0 mm hard stainless steel wire.

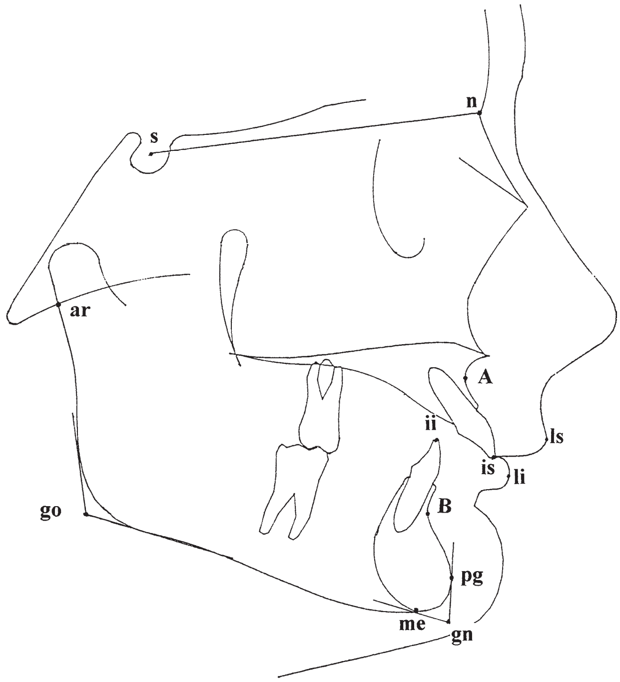

Figure 2 Reference points used in the cephalometric analysis. The definitions of the reference points are those given by Droschl (1984).

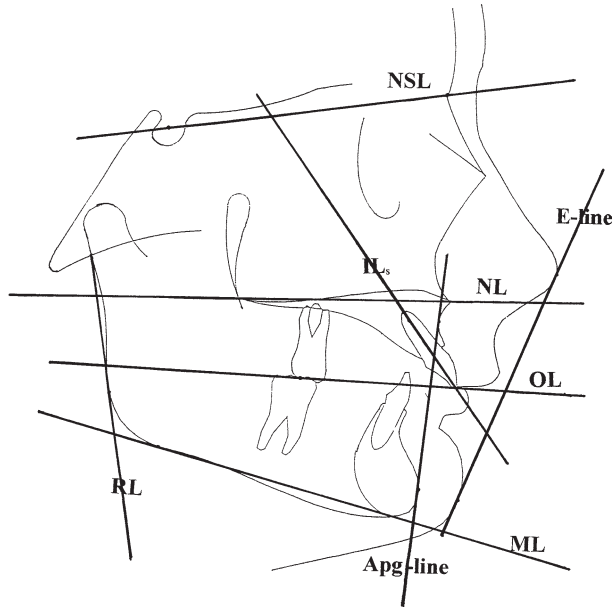

Figure 3 Reference lines used in the cephalometric analysis. Definitions of ML, NL, NSL, OL, RL, and Ils lines are those given by Björk (1960). The Apg and E-lines have been defined according to Ricketts (1957)

Cephalometric analysis

All radiographic registrations of the patients were made with the same X-ray equipment and by the same operator. The head films were exposed with the patients standing with the teeth in centric occlusion (intercuspal position: ICP). The enlargement factor was 9.1 per cent. Corrections for linear magnification were not made.

A matte acetate tracing film was placed on the lateral head film and relevant reference points (Figure 2) and lines (Figure 3) were marked with a pencil (0.3 mm 2H). All tracings were digitized with a Scriptel RTD digitizer (Scriptel Corporation, Toronto, Canada), and measurements of the angular and linear variables listed in Table 1 were performed with an accuracy of 0.1 mm or 0.1 degree using the Dentofacial Planner computer program (Dentofacial Planner Software Inc., Toronto, Canada).

The evaluation of treatment changes was carried out by comparing the pre- and post-treatment tracings. This procedure was based on superimposition of the tracings on stable cranial base structures according to the technique described by Björk and Skieller (1983).

The corresponding individual measurements in the control material were obtained directly from the author (Droschl, 1984). The magnification factor of the cephalometric data of the control material was not known. However, in order to be able to compare linear measurements in patients and controls, it was necessary to establish the magnification factor in the control group. A conceivable way of obtaining an acceptable estimation of the magnification factor would be to calculate it on the basis of the length of the cranial base. Craniometric studies of Caucasian, African, and Asian skulls of different ethnic origins and shapes have shown that the variability of

Table 1 The intercept values of the variables recorded in the patients and controls at 14.2 years of age (pre-Herbst). The level of statistical significance of differences between the groups was calculated with *t*-test.

Variables	Intercept values		Difference	*t*-value
	Patients $n=30$	Controls $n=47$		
Angular				
SNA	81.4	81.6	−0.2	−0.355
SNB	75.3	76.1	−0.8	−1.155
ANB	6.1	5.5	0.6	1.739
ML/NSL	31.0	32.2	−1.2	−0.911
NL/NSL	7.7	7.2	0.5	0.741
ML/NL	23.3	25.0	−1.6	−1.657
snpg	77.0	78.4	−1.4	−1.813
RL/ML	121.2	124.7	−3.5	−2.306*
Ils/NSL	106.2	104.6	1.6	0.870
Linear				
n-me	123.3	121.4	1.9	1.200
s-gn	131.1	130.6	0.5	0.375
s-go	83.0	80.9	2.1	1.500
is-npg	10.9	9.7	1.2	1.298
ii-npg	1.3	3.2	−1.9	−2.625*
ii-Apg	−1.9	0.0	−1.9	−3.166**
Overjet	9.3	7.5	1.8	3.400***
Overbite	4.1	5.4	−1.3	−2.943**
ls-E-line	−0.2	−0.9	0.7	1.214
li-E-line	−0.8	−0.1	−0.7	−1.000

*$P<0.05$, **$P<0.01$, ***$P<0.001$.

cranial base length is small (Martin and Saller, 1959, Kuroe *et al.*, 2004). Roentgen cephalometric studies of the length of the anterior cranial base of individuals with different ethnic backgrounds have also shown that the mean values and standard deviations are comparable in the different groups (Solow and Sarnäs, 1982; Kerr and Ford, 1986, Dibbets and Nolte 2002). To the best of our knowledge, a comparison of anterior cranial base length between Swedish and Austrian subjects has not been carried out. However, there is no reason to believe that such a comparison would produce a result which differs from those of previous studies in this field. When not corrected for radiographic enlargement, the anterior cranial base length at the start of Herbst treatment was on average 75.3 mm in the patient group. The corresponding measurement in the control group was on average 75.0 mm. Post-Herbst these distances were 76.9 and 76.5 mm, respectively, in the treated and control groups. On the basis of these observations, it was considered reasonable to assume that the magnification factors which apply to the two groups were nearly identical.

Measurement error

Two-thirds of the patient cephalograms had been analysed by one author (PH) and one-third by another author (SS) Before the start of the tracing procedure, a calibration was performed between the examiners as regards the identification of the landmarks. The concordance in landmark identification was tested by double determinations of the relevant angular and linear measurements of 10 randomly chosen head films. The interindividual method errors (s_i) were then calculated according to Dahlberg's (1940) formula:

$$s_i = \sqrt{\frac{\Sigma d^2}{2n}},$$

where '*d*' is the difference between the first and second measurements and '*n*' is the number of double determinations. The method errors of the angular measurements were found to vary between 0.2 (ANB) and 0.9 (RL/ML) degrees, with the exception of the variable Ils/NSL which exhibited an error of 1.7 degrees. The method error of the linear measurements varied between 0.5 and 0.6 mm.

The influence of the method error on the cephalometrically determined treatment changes was evaluated using the pre- and post-Herbst head films of 20 randomly selected patients. Tracings and measurements of both the pre- and the post-Herbst films of each patient were performed on two occasions with an interval of at least 3 months. The post-Herbst tracings obtained on the first occasion were superimposed on their respective pre-Herbst tracings and the sizes of the changes (changes A) which had occurred during treatment could be determined. Subsequently, the corresponding changes (changes B) were determined on the basis of the second set of pre- and post-Herbst tracings. Finally, the differences between changes A and B were entered into Dahlberg's (1940) formula (see above) and a combined method error, which included errors in the location of landmarks as well as superimposition and measurement errors, could be calculated for each variable. The method error for linear variables varied between 0.5 (ii-Apg, ii-npg, is-npg, overbite, Li-E-line) and 0.8 mm (s-gn). The corresponding values for angular measurements were 0.5 (SNB, ANB, snpg) and 1.4 degrees (Ils/NL).

In the control material, the method error according to Dahlberg's (1940) formula (based on double determinations carried out on 12 cephalograms) varied between 0.3 (is-npg) and 1.2 (overbite) mm for linear measurements and between 0.7 (snpg) and 1.5 (ML/NL) degrees for angular measurements (Droschl, 1984).

Statistical analysis

Within the treatment and control groups, a regression line of the pre-Herbst cephalometric measurements on age was calculated for each variable: $y = a + b \times \text{age} + c \times \text{group}$. The observations for each variable were plotted in diagrams in order to check that the linear regression actually gave a reasonable fit. Through geometric translation of the y-axis, the intercepts (a) and the standard errors of the intercepts were calculated (Draper and Smith, 1966) at the age of 14.2 years, which was the mean age at the start of treatment. Comparisons of the estimated intercepts (a) for patients and controls were then performed with the independent t-test. Corresponding regression lines were formed for the post-Herbst cephalometric measurements, and comparisons were then made of the calculated intercepts for patients and controls at 14.9 years, which was the mean age at the end of the treatment with the Herbst mechanics.

Differences between the pre- and post-Herbst cephalometric measurements in the patient group were tested for significance with a paired t-test.

Results

The cephalometric variables in the Herbst and control groups before treatment are compared in Table 1. With the exception of RL/ML, which was 3.5 degrees larger in the control group ($P < 0.05$), there were no significant differences between the skeletal variables of the patient and control groups. However, the linear variables which describe the position of the incisors differed, on average, between 1.3 and 1.9 mm between the groups. These differences could partly be explained by the fact that alignment of teeth, and in some cases also intrusion of the incisors, had been carried out in the patients before insertion of the IHA.

Table 2 shows the changes which occurred in the patients during treatment with the IHA. With the exception of the variables NL/NSL, RL/ML, and Li-E-line, all linear and

Table 2 Mean changes ($\bar{d}$) and standard deviations (SD) of the cephalometric values after 0.7 years of treatment with the integrated Herbst appliance in 30 boys.

Variables	$\bar{d}$	SD	*t*-value
Angular			
SNA	−1.1	1.20	−4.788***
SNB	1.1	0.83	7.097***
ANB	−2.1	1.23	−9.454***
ML/NSL	−0.4	0.94	−2.439*
NL/NSL	0.4	1.23	1.697
ML/NL	−0.8	1.07	−4.185***
snpg	0.9	0.70	7.022***
RL/ML	0.3	1.46	1.304
Ils/NSL	−5.2	5.86	−4.891***
Linear			
n-me	2.7	1.32	11.174***
s-gn	3.8	1.45	14.271***
s-go	2.7	0.96	15.074***
is-npg	−4.5	1.76	−14.112***
ii-npg	2.8	1.59	9.516***
ii-Apg	4.2	1.88	12.230***
Overjet	−7.1	1.89	−20.563***
Overbite	−2.3	1.83	−7.160***
Ls-E-line	−2.1	1.27	−9.112***
Li-E-line	0.3	1.31	1.146

*$P < 0.05$, ***$P < 0.001$.

Table 3 The intercept values of the variables recorded in the patients and controls at 14.9 years of age (post-Herbst). The level of statistical significance of differences between the groups was calculated with the t-test.

Variables	Intercept values		Difference	*t*-value
	Patients $n=30$	Controls $n=33$		
Angular				
SNA	80.3	81.8	−1.5	−1.361
SNB	76.4	76.1	0.2	0.247
ANB	3.9	5.7	−1.7	−3.941***
ML/NSL	30.6	31.6	−1.0	−0.695
NL/NSL	8.1	7.6	0.5	0.640
ML/NL	22.5	24.0	−1.5	−0.894
snpg	77.9	77.9	0.0	0.019
RL/ML	121.6	123.3	−2.1	−1.255
Ils/NSL	101.0	104.3	−3.3	−1.434
Linear				
n-me	126.0	123.3	2.7	1.476
s-gn	134.9	131.8	3.1	1.830
s-go	85.6	82.4	3.2	2.037*
is-npg	6.4	9.5	−3.1	−2.993**
ii-npg	4.0	2.6	1.4	1.759
ii-Apg	2.3	0.5	1.8	2.590*
Overjet	2.5	7.9	−5.4	−8.616***
Overbite	1.9	5.2	−3.3	−6.149***
Ls-E-line	−2.3	−0.9	−1.4	−1.397*
Li-E-line	−0.5	−0.4	−0.1	0.099

Levels of significance: *$P<0.05$, **$P<0.01$, ***$P<0.001$.

angular measurements exhibited statistically significant and favourable changes.

After an average treatment time of 8 months 13 days (0.70 years) with the IHA, the ANB angle in the patient group was significantly smaller than that of the control group ($P < 0.001$; Table 3). In the vertical plane, the patients exhibited a significantly greater posterior face height (s-go) than the controls ($P < 0.05$) post-Herbst. As regards dental measurements, there were six significant differences between the patients and controls. The distance between the incisal edge of the upper incisors and the npg line was reduced in the treatment group and was significantly smaller than in the controls ($P < 0.01$). The incisal edge of the lower incisors had been anteriorly displaced as a result of IHA treatment and, in relation to the Apg line, this distance was significantly larger ($P < 0.05$) in the patients as compared with the controls.

The significant changes in incisor positions in the patients were also reflected in the overjet value, which was normal after treatment. In the control group, this value was 7.9 mm and significantly larger than in the treatment group ($P < 0.001$). The overbite had been reduced to 1.9 mm in the patients, while no such change had occurred in the controls, and the mean values in the two groups were significantly different ($P < 0.001$).

Finally, normalization of the overjet in the patient group resulted in an improved upper lip position in relation to the E-line, and this variable value was significantly smaller in the patient group as compared with the controls ($P < 0.05$).

Discussion

The effects of 0.70 years of treatment with the IHA on dental and skeletal variables in a group of male patients with a post-normal malocclusion were evaluated in this investigation. The study was performed on cephalograms taken of clinical material which was well defined as regards gender, skeletal maturation, diagnosis, and method of treatment. It would have been desirable to have access to control material of similar quality. However, for ethical reasons it is no longer possible to perform longitudinal roentgenologic registrations of untreated patients with post-normal occlusion. As a compromise, therefore, it was considered acceptable to use cross-sectional material comprising age-matched untreated males with post-normal occlusion (Droschl, 1984) as a control group.

Information regarding the roentgenographic enlargement was lacking for the control material. However, a comparison of the average anterior cranial base length in the patient and control groups showed that these values were nearly identical. Studies have shown that cranial base length exhibits very little variation between groups of different ethnic origins (Martin and Saller, 1959; Dibbets and Nolte, 2002; Kuroe *et al.*, 2004), and on this basis it is reasonable to presuppose that the roentgenographic magnification factor was the same in the two materials.

As regards incisor relationship, the subjects in the patient group exhibited somewhat greater deviations from normal cepahlometric standards than the controls. An exception from this common pattern was the overbite, which was more pronounced in the controls. The reason for this was that in patients with overerupted incisors and/or a 'gummy smile', active intrusion of the upper incisors was carried out before insertion of the IHA. Naturally, these tooth movements caused a reduction in the size of the overbite.

The correction of the post-normal occlusion, overjet, and overbite was achieved by a combination of skeletal and dental treatment effects. SNB increased on average by 1.1 degrees, from 75.3 to 76.4 degrees. This increase could be attributed entirely to the effect of the Herbst treatment, as no such change was found in the control group. There was a similar relationship between the changes of the snpg angles in the two groups, i.e., a significant increase was recorded in the patients, whereas the controls did not show any change.

In other studies of the effects of Herbst treatment, the reported changes in SNB vary between 0.2 and 1.9 degrees (Pancherz, 1982; Valant and Sinclair, 1989; McNamara *et al.*, 1990; Wong *et al.*, 1997; Manfredi *et al.*, 2001; Schaefer *et al.*, 2004). In those investigations, the subjects were both males and females and the patients have usually been younger than those in the present study. Furthermore, treatment times from 6 to 13 months have been used, and the designs of the Herbst appliances have varied. It may not be relevant, therefore, to make a direct comparison between the present SNB changes and those of previous studies. It can be stated, however, that the degree of anterior displacement of the mandible which was achieved with the IHA bears a resemblance to the corresponding effects produced by Herbst appliances of other designs.

A further measurement which indicated that favourable anterior repositioning of the mandible had taken place was the distance s-gn, which increased by 3.8 mm in the treated group. In the control group the corresponding change was 2.3 mm.

SNA was found to have been significantly reduced. When compared with corresponding data presented by other authors (Pancherz, 1982, Valant and Sinclair, 1989; Wong *et al.*, 1997; Manfredi *et al.*, 2001), the reduction of SNA was twice as great in the present study. This could very well be due to differences in the design and efficacy of the appliances used. When treatment is carried out with the IHA, all teeth are bonded and aligned, and a heavy rectangular wire is inserted and bent distal of the molar tubes in the upper and lower dental arches before correction of the post-normality with the Herbst mechanism is commenced. The posteriorly directed functional force transferred by the IHA to the upper teeth is thus distributed over the whole dental arch. This force could also be assumed to produce a lingual root torquing effect on the incisors and, as a result of this, a possible remodelling of the alveolar bone in the subspinale area and a concomitant posterior displacement of point A. Consequently, the relatively large reduction of SNA recorded for the patients in the present study was probably the result of the combined effects of restriction maxillary anterior growth and bone remodelling. The fact that one of the force components, which was generated by the IHA, gave a certain degree of torquing on the upper incisors may also explain why the considerable average reduction of overjet by 7.1 mm in the patients only caused a moderate retroclination of these teeth.

Although Class I occlusions with normal overjet and overbite were achieved through treatment with the IHA, it is obvious that the treatment did not entirely correct the skeletal post-normality. The mean values of the variables SNB and snpg indicated that a retrognathic mandible still existed, and the average post-treatment ANB angle was 3.9 degrees. This value exceeds the norm for orthodontically untreated Swedish males of the relevant age and with a Class I occlusion by approximately 1.5 degrees (Thilander *et al.*, 2005). In spite of this skeletal problem, normal occlusions could be achieved through dental compensations related to the upper incisors which were somewhat retroclined and the lower incisors which were slightly more anteriorly positioned than normal after treatment.

During adolescence, the mandible normally exhibits an anterior growth rotation which is reflected in a continuous small decrease of ML/NSL (Riolo *et al.*, 1974; Bhatia and Leighton, 1993; Thilander *et al.*, 2005). This pattern of development was also found in the untreated control group in which this angle decreased from 30.7 to 30.5 degrees during the period of the investigation. Most studies of the effects of Herbst treatment have reported the occurrence of a small posterior rotation of the mandible, i.e., the ML/NSL angle has increased (Pancherz, 1982; Wieslander, 1984; Valant and Sinclair, 1989; Wong *et al.*, 1997; Du *et al.*, 2002; Schaefer *et al.*, 2004). In contrast to this, a significant mean decrease of 0.4 degrees of ML/NSL was recorded in the present study, a change which is comparable with that of the normal pattern of mandibular growth rotation. Du *et al.* (2002) reported a similar reduction of the mandibular plane angle in patients who had been treated with a 'splinted' Herbst appliance in combination with high-pull headgear and with a step-by-step advancement of the mandible.

One factor which may indirectly reduce the risk of posterior rotation of the mandible during treatment with the IHA is the intrusion of the incisors with fixed appliances which is carried out before insertion of the Herbst mechanics. This adjustment of the curve of Spee makes it possible to jump the mandible forward to an edge-to-edge incisor relationship with only a small concomitant posterior rotation of the mandible and opening of the bite in the lateral segments. Moreover, the vertical vector of the functional force which is transferred by the IHA to the teeth may have an intrusive effect on the posterior segments of the maxillary dentition. This effect is beneficial and may also counteract the tendency of posterior mandibular rotation which has been reported in previous studies (Pancherz, 1982; Wieslander, 1984; Valant *et al.*, 1989; Wong *et al.*, 1997; Du *et al.*, 2002; Schaefer *et al.*, 2004).

Anterior (n-me) and posterior (s-go) face heights increased on average by 2.7 and 2.6 mm, respectively, in the patient group. In the control group, n-me increased from 122.5 to 124.6 mm (2.1 mm) and s-go from 82.6 to 84.4 mm (1.8 mm). These changes in vertical facial dimensions are within normal limits in boys at this stage of dentofacial development.

With respect to dental changes, the IHA treatment resulted in increased values of the variables ii-Apg and ii-npg and a reduction of is-npg, that is, anterior repositioning of the lower incisors and posterior repositioning of the upper incisors had occurred. The overjet and overbite decreased significantly by 7.1 mm and 2.2 mm, respectively, and after treatment both these measurements were normal. In the control group, no such favourable dental changes were recorded. On the contrary, both overjet and overbite showed a tendency to increase during the period of the investigation. In other studies of the effects of Herbst treatment, the average overjet reductions have varied between 5.1 and 10.4 mm (Pancherz, 1982; Wong *et al.*, 1997; Du *et al.*, 2002; Schaefer *et al.*, 2004).

Correction of the incisor relationship in the patient group significantly improved the position of the upper lip in relation to the E-line, whereas the lower lip position showed only a small and not significant average change. In the control group, no significant changes of these variables were recorded. The mean values for upper and lower lip position in relation to the E-line in Swedish 15-year-old males with normal occlusion are −3 mm and −2 mm, respectively (Forsberg and Odenrick, 1979). Consequently, correction of the post-normal malocclusion had lead to a nearly normal upper lip position (−2.3 mm), whereas the lower lip still exhibited moderate protrusion after treatment (−0.5 mm).

The treatment with the IHA described in this study was followed by a finishing stage which took on average 5.9 months. Thus, the total mean treatment time including the alignment, Herbst, and finishing stages was 23.9 months. Bearing in mind the severity of the malocclusions, this treatment time seems reasonable. Furthermore, the fact that neither the fabrication nor the possible repair of the IHA requires any involvement by a dental technician facilitates the clinical work and reduces the risk for unnecessarily long interruptions in treatment due to broken appliances.

Conclusions

Eight months of treatment with the IHA was carried out in a group of boys in the MP3 stage of maturation. A Class I dental arch relationship was achieved in all subjects. A moderate skeletal post-normality still existed after treatment, although the therapy resulted in a significant increase of SNB and a significant decrease of SNA.

IHA therapy seemed to produce a somewhat greater reduction in SNA than treatment with Herbst appliances of other designs. Furthermore, the posterior mandibular rotation, which is a common finding in connection with Herbst appliance treatment, was not seen in the patients treated with the IHA.

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